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A Rudimentary Design of Remote Controlled RRR Manipulators

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Abstract : The rise in Industrial Automation has increased the need for better control of robotic manipulators. This paper aims to bridge the communication gap between the user and the robot with the usage of android apps. The consistent output of a robotic system along with quality and repeatability are unmatched.

Keywords: Inverse Kinematics,Arduino, MIT App Inventor, HC-05 Module, Servo Sizing, Manipulator.

1. INTRODUCTION

Currently industrial robot manipulators have become indispensable for increasing productivity and improving the efficiency of automated production lines where they are used for a large variety of tasks, such as materials handling, pick and place operations, welding and painting. They are often used to perform duties that are hazardous or difficult for humans. In recent times robots are generally controlled by sophisticated software specially developed by the robot manufactures that enable controlling only that specific robot. It also requires special understanding of that software to enable any changes to be done. Specially trained workers have to be employed in order to change the working setup and to service the machine which opposes the main aim of automation to reduce manual intervention. The existing control methods are complex in nature and the time consumed for implying any changes is more which affects the manufacturing time of a product by increasing the non-value added time. Hence an alternative control method has to be developed which overcomes all the above briefed problems.

Smartphone, a small yet powerful device is rapidly changing the traditional ways of human-machine interaction. They are mobile phones built on a mobile computing platform, with more advanced computing ability and connectivity than ordinary phones. Smartphones are usually implanted with Bluetooth module and are powered bydifferent operating systems such as Symbian, Bada, and Android OS etc.Among all available mobile operating systems Android OS has gained significant popularity after being launched in 2008, due to its open architecture. Android platform has revolutionized the application development field for smartphones, opening new doors for technical advancement and exploration.There are various modes of communication between the microcontroller of the robot and the Smartphone. However, the popularly used means of communication is done via Radio Frequency, Bluetooth or Wi-Fi. Using Radio Frequency limits the distance from which the robot can be controlled. Using Wi-Fi increases the overall cost for setup. So, the robot has been built with Bluetooth which has intermediate range of distance covered and cost between Radio Frequency and Wi-Fi. Thus this research focuses on developing a state of the art control method for a custom designed and manufactured RRR robot through a Bluetooth module available in a smartphone by developing a simple application that can be run on the Android OS of the smartphone.

2. METHODOLOGY

2.1 CONTROL APPLICATION:

Control application manages commands and directs the behavior of the robotic arm. The application was created using MIT APP INVENTOR. This application runs on any android device present with Bluetooth capabilities. The application consists of three interfacing screens. One is the home screen which directs to the other two screens. The forward and inverse kinematics of the robot is controlled from two separate screens. There is no need for an external computer to each time modifies the parameters and variables. Once the robot is connected to the application, the whole system is closed and there is only end to end communication. The angles can be given directly in case of forward kinematics using the slider. In the case of inverse kinematics, the end position can be specified directly and the corresponding angles of the servos will be displayed on the screen. The user interface of the app is really lucid. The app even supports voice recognition where the values can be told directly. The app processes the vocal data using Google's speech recognition and sends it to the Arduino directly via Bluetooth. The app also has a voice response system which lets you know the current status of the robot and the application.

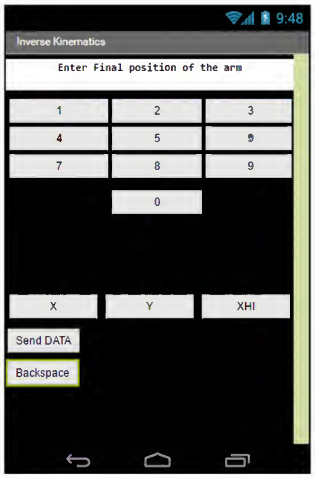

Figure 1 : Depiction of Inverse Kinematics

Figure 2 : Depiction of Forward Kinematics

2.2 SERVO SIZING:

The next phase was the selection of appropriate actuation mechanism for the movement of the arms. Servo motors were selected instead of using a stepper motor and a bridge drive because programming of servo motors was really lucid using Arduino and also it gives a feedback on the current position of the robotic arm which is useful in error rectification. The selection of motors was based on a simple theory. Torque requirement is at the maximum when the arm is fully stretched. So assuming the worst case scenario possible and with a safety factor ‘2’ the torque required at each revolute joints were calculated. Only the static torque was calculated while the inertial torque requirement gets accounted in the safety factor. The reason for this is that moment of inertia might vary from part to part and it is difficult to calculate it individually with great accuracy.

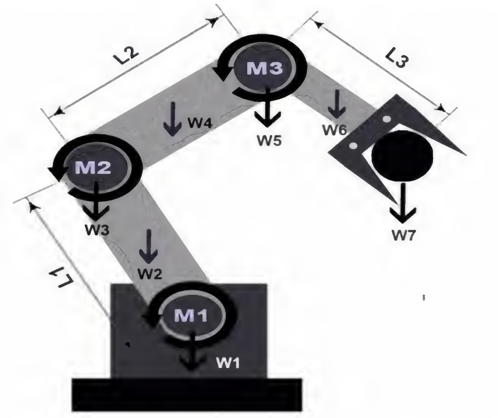

Figure 3 : FBD of Robotic arm

The above figure represents the free body diagram of the Robotic arm

Terminology

L_1- length of arm 1
M_0-Base Motor
L_2- length of arm 2
M_1-Motor actuating Arm 1
L_3-length of wrist
M_2-Motor actuating Arm 2
W_1-self weight of M1
M_3-Motor actuating Wrist
W_2-weight of arm 1
l1 – C.G of arm 1
W_3-self weight of M2
l2 – C.G of arm 2
W_4-weight of arm 2
l3 – C.G of arm 3
W_5-self weight of M3
W_6-weight of wrist
W_7-applied load = 250g (payload)

WRIST:

The torque was found to be **0.2176 Nm**

To meet the required torque,**Futaba S3003** Servo Motor is selected.

Torque	4.8v: 3.2 kg-cm 6v: 4.1 kg-cm
Speed	4.8v: 0.23 sec/ 60 deg 6.0v: 0.19 sec/ 60
Weight	37 g

Table1 : Specification of Futaba S3003 servo

ARM 2:

The torque was found to be 1.124 Nm

To meet the required torque, **Vega v0150 Servo Motor** is selected.

Table2 : Specification of V1050 Servo motor

Dimension	40.7mm x 20.5mm x39.5mm
Torque	15.5kg/cm at 4.8V, 17kg/cm at 6V
Weight	77 g.

ARM 3:
The torque was found to be **2.46 N.m.** To meet the torque requirements, Two of **Vega v0150 Servo motor**s is selected and are mounted on either side of the arm.

2.3 ROBOTIC ARM:

The robotic arm is a class 5 robot. It is receiving end of the system. It consists of a total number of 6 servos which grant the system 5 DOF (degrees of freedom). The microcontroller used is the Arduino UNO R3 which controls the servo by sending data accordingly. The Arduino UNO receives the input command from the HC-05 Bluetooth module, processes it and sends the data to the servo motors according to the user's need. The microcontroller, power source and the Bluetooth module are secured in a hollow wooden box which acts as a base to the robotic arm. The whole framework of the robotic arm is made up of ABS plastic with a material fill of 60%. The strength is achieved through hexagonal structure packing which also results in light weight of parts. The base servo is also attached to the wooden box which supports a 0-180^{0}degree movement about the vertical axis. The servo bracket is mounted above this servo directly. The servo bracket consists of two servo motors which share the torque requirement for actuating arm 1. The most complicated part of the robotic arm is the arm2. It houses two servo motors in which one actuates the arm itself and the other for actuating the wrist. The wrist supports any kind of end effector. The end effector used in this case is a mechanical gripper. The grabbing action is achieved through the usage of a mini servo and gears.

Figure 4 : 3D Printed model of manipulators

2.4 CONSTRUCTIONAL DETAILS:

The system developed by us consists of the following parts:

TRANSMITTING END (User's end)

1. An android phone

RECEIVING END

1. HC-05 Bluetooth module
2. 6 nos. Servo motors
3. Arduino UNO R3 with Atmega 328p microcontroller
4. Framework
5. End effector

The assembly details are explained in the following steps:

STEP 1-BOARD:
ARDUINO UNO:It contains Atmega 328p microcontroller. It has 14 digital Output/Input pins (of which 6 can be used as PWM signals), 6 analog inputs, a 16 MHz crystal oscillator. Operating voltage of the micro controller is 5V to 12V. It contains 32 KB of flash memory enough to store the program data for this project.

STEP 2-COMMUNICATION:
The communication between the receiving and transmitting end is done wirelessly. This is achieved using Bluetooth communication between the robotic arm and the android phone. HC-05 module was used in the process. HC-05 module is an easy to use Bluetooth SPP (Serial Port Protocol) module, designed for transparent wireless serial connection setup.

CHARACTERISTICS:

- Typical -80dBm sensitivity.
- Up to +4dBm RF transmits power.
- Low Power 1.8V Operation, 3.3 to 5 V I/O.
- PIO control.
- UART interface with programmable baud rate.
- With integrated antenna.
- With edge connector.

The name and slave/master configuration can be done using AT commands.

PIN OUT CONFIGURATION

Figure 4 : Pin out Configuration

APPLICATION CIRCUIT

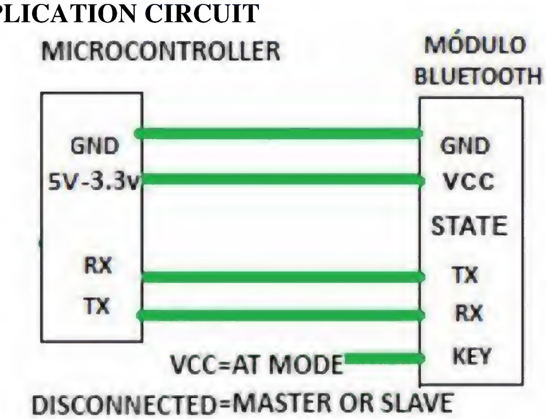

Figure 5 : Application Circuit

STEP 3 – ROBOT MECHANISM:

The moving mechanism of the robotic arm is controlled using the Arduino developmen board. Each end of the robotic arm is directly coupled to the servo plate which is in turn held to the motor shaft with the help of a gear head. The robotic arm consists of 3 joints in which total of 6 servos were used. 4 used to control the actuation of these joints, 1 to actuate the servo bracket and the last one to actuate the mechanical gripper.

STEP 4 – WORKING PROTOCOL:

2.5 FUNCTIONING OF THE ROBOTIC ARM:

The payload weight of the arm is around 250 g. The system is turned ON. The user connects with the robot using his phone. The robot is listed in his “Bluetooth available devices” list. Once connected, the robot will follow orders from the user. The user can transmit data wirelessly from a distance of 10m. There is a separate slider for controlling the gripper in the app. The position of the gripper is controlled using that.

3.0 CONCLUSION

In this paper, the design and implementation of RRR manipulator is presented and developed using Arduino microcontroller and Android Smartphone. An algorithm has been provided and its working is detailed thoroughly. Since the updating possibilities are endless, updating the system has been kept as a future scope. The devised method for controlling the manipulator using a smartphone is both simple and cost effective compared to the already existing method.As an end thought, the system can be improved further and implemented in large scale.

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